How cytoplasmic DNA undergoes adaptation to avoid harmful mutations

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About 1.5 to 2 billion years ago, the great evolutionary 'big fish, little fish' engulfment occurred. Somehow, scientists think, one bacteria swallowed another, creating a new type of cell, the eukaryotes.

Life hasn't been the same since.

Eukaryotes, though they carry their own DNA in their nucleus, which is passed on every generation, also harbor a stew of DNA from their evolutionary past within their cytoplasmic soup. This DNA, which includes mitochondria in animals and plastids in plants, are the powerhouses of the cell, and are normally only passed down maternally.

But do these cytoplasmic DNA also undergo adaptation within the confines of the cell? And if so, how do they pull off this feat while seemingly having one evolutionary arm tied behind its back? You see, cytoplasmic DNA can't easily swap out harmful mutations like nuclear DNA (side note: neither can the male Y chromosome, which is why it is slowly shrinking).

Only nuclear DNA can maintain the best mutations and remove bad ones by reshuffling its genome like a deck of cards during reproduction after sperm meets egg. This reshuffling allows nuclear DNA to adapt. For mitochondria and plasmids, there is only asexual reproduction.

Now, University of Sydney School of Life and Environmental Sciences researchers Joshua Christie and Madeleine Beekman, have used

computational tools to better understand cytoplasmic DNA adaptation and how they promote beneficial mutations —-and more importantly, avoid harmful mutations which could become like Trojan horses to affect the whole cell, and thereby, the health of an organism.

"Why is the mitochondrial genome still going strong after 1.5-2 billion years?" asked co-author Beekman. "It all comes down to the fundamental difference between male and female sex cells, or gametes. While each sperm cell contains one sex-chromosome (either an X or a Y), each egg cell contains many mitochondria. Because mitochondria are essential to cell function, after all they provide the energy, egg cells that contain faulty mitochondria are selected against. As a result, only egg cells that contain a full complement of healthy mitochondria stand a chance to produce a zygote."

The study shows how efficiently the biology of cytoplasmic genomes—specifically their organization into host cells and their uniparental inheritance—can allow them to accumulate beneficial substitutions and to purge deleterious substitutions faster than free-living sexual genomes.

"So, while males are happy to pass on any Y-chromosome to their sons, females appear to take the future of their offspring a little more seriously," said Beekman.

In addition, the general insights gained from the study can be applied broadly to understanding adaptation for other cytoplasmic genomes. In addition to mitochondria, these include plastids and obligate endosymbionts such as *Rickettsia*, *Buchnera* and the *Wolbachia* parasite.

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